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Epidemic of *Serratia marcescens* Bacteremia in a Cardiac Intensive Care Unit

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From 16 July through 27 September 1988, seven cases of nosocomial *Serratia marcescens* bacteremia occurred in a cardiac care unit. In all seven case patients, *S. marcescens* was isolated from blood cultures. Two of the seven had other microorganisms identified in the blood culture in which *S. marcescens* was recovered; one had *Enterobacter cloacae*, and one had *Klebsiella pneumoniae*. A case-control study was conducted to identify risk factors for bloodstream infection. Case patients were more likely than controls to have been exposed to an intra-aortic balloon pump pressure transducer (7 of 7 versus 6 of 21; $P = 0.001$) and to a pulmonary arterial pressure transducer (7 of 7 versus 8 of 21; $P = 0.005$). Cultures of in-use and in-storage transducers revealed bacterial contamination of the pressure-sensitive membranes of the transducers. *S. marcescens* blood culture isolates obtained from five of the seven case patients, as well as six *S. marcescens* isolates from cultured transducers, belonged to serotypes Oundetermined:H1 and Oundetermined:H18. *E. cloacae* isolates from one case patient and from two stored and two in-use transducers had identical antimicrobial suceptibility patterns. Review of cardiac care unit disinfection practices revealed that the transducers were not processed with high-level disinfection or sterilization between patient uses. We concluded that the transducers had served as reservoirs for this outbreak of bloodstream infection. Because intra-aortic balloon pumps with pressure transducers are being used more frequently in the management of critically ill cardiac patients, their role as infectious reservoirs should be considered in the investigation of nosocomial bacteremia.

Pressure transducers for hemodynamic monitoring are frequently used in the management of critically ill patients (11). Reusable pressure transducers are used in conjunction with indwelling intravascular catheters to measure pulmonary or peripheral arterial pressures, or they can be used with intra-aortic balloon pumps (IABPs) to measure left ventricular pressures.

The Centers for Disease Control (CDC) recommends high-level disinfection or sterilization of pressure monitoring transducers before reuse (3). However, epidemic bloodstream infections associated with contaminated pressure transducers have been a persistent problem (1). We report an outbreak of *Serratia marcescens* bacteremia among patients in a cardiac care unit (CCU) associated with the use of IABPs and reusable pressure transducers.

Background. Hospital A, a 465-bed nonteaching community hospital, performs approximately 400 open-heart surgeries (OHS) per year. Patients are usually admitted to the eight-bed CCU following OHS or percutaneous transluminal coronary angioplasty or for medical management of myocardial ischemia. In September 1988, infection control personnel identified *S. marcescens* bacteremia occurring over a 2.5-month period in seven CCU patients. An epidemiologic and laboratory investigation of the suspected epidemic of nosocomial bacteremia was begun, and the CDC was asked to assist in the investigation.

MATERIALS AND METHODS

Case definition and case ascertainment. To begin our investigation, we defined a case patient as any hospitalized patient with a blood culture positive for *S. marcescens* from 16 July through 27 September 1988. To determine the background rate and identify all potential cases, we reviewed the nosocomial infection records from 1 January 1986 through 27 September 1988. These records included all positive cultures from any site, by patient location, which were obtained at least 48 h after the patient was admitted to the hospital.

Epidemiologic methods: case-control study. To identify risk factors for *S. marcescens* bacteremia, we reviewed the charts of the case patients and selected controls to conduct a case-control study. Controls consisted of a random sample of patients who (i) were in the CCU on the same day as a case patient; (ii) had no blood or intravascular catheter culture positive for any microorganism; and (iii) if no blood or intravascular catheter culture was done, had no clinical evidence of a bloodstream infection. A total of three controls per case were selected by using the daily patient census records of the CCU.

The medical records of all study patients were reviewed for the following information: age; weight; admission diagnosis; length of stay in hospital and CCU; severity of illness as measured by the acute physiologic and chronic health evaluation (APACHE II) (8) at the time of admission; surgical and nonsurgical invasive procedures; mechanical ventilation; use of antimicrobial agents; discharge status; and presence and duration of major intravascular lines, including arterial line (A-line), Swan-Ganz pulmonary arterial pressure line (PA-line), and IABP. For case patients, exposures were evaluated for the period between the date when the exposure began and the date of the *S. marcescens*-positive blood culture. For controls, exposures were evaluated for the period between the date when the exposure

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began and the date of the *S. marcescens*-positive blood culture of the corresponding case patient.

A univariate analysis compared case and control patients for the presence of risk factors. The statistical association between risk factors and outcome was tested by using the two-tailed Fisher's exact test for categorical variables and Student's *t* test for continuous variables. When indicated, we compared the medians of numeric variables by the Kruskal-Wallis test (10). Multivariate analysis with the logistic regression technique was used to identify those independent variables useful for the prediction of *S. marcescens* bacteremia.

Laboratory methods. On 27 September 1988, the pressure-sensitive membranes of seven pressure transducers, five found in storage in the CCU and two that were attached to a PA-line and an A-line being used on a case patient, were cultured. Culture of the membranes was done by using sterile swabs moistened with sterile nonbacteriostatic saline solution. The specimens were plated onto tryptic soy agar with 5% sheep blood. Isolates obtained from the transducer membranes and the tips of PA-lines and A-lines and all blood culture isolates from case patients were sent to the CDC for confirmation, serotyping, or plasmid analysis.

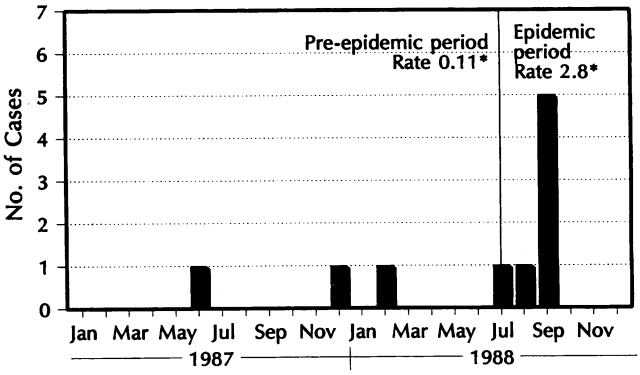
S. marcescens O antigen was determined by means of a tube agglutination test described by Ewing (6). Flagellar H antigens were determined by using the H-immobilization test of Le Minor (12).

Plasmid analysis on the *Enterobacter cloacae* isolates was performed by the procedure of Birnboim and Doly (2). Vertical electrophoresis was done in a 0.85% agarose gel using Tris-borate (89 mM Tris, 89 mM boric acid, 2.5 mM EDTA [pH 8.3]) buffer for 3 h at 35 mA. The gel was then stained with ethidium bromide and photographed. *E. cloacae* identifications and antimicrobial susceptibility patterns were determined at the hospital by using the Vitek GNF-K card (Vitek Systems, Inc., St. Louis, Mo.).

Procedure review. We conducted a review of the equipment and utilization of pressure monitoring lines. In general, intravascular catheters for monitoring pulmonary arterial pressures and the IABPs were inserted by the attending physicians in the cardiac catheterization laboratory. A-line catheters were inserted by the operating room, cardiac catheterization laboratory, emergency room, or CCU nursing staff. The IABPs were usually inserted in the cardiac catheterization laboratory, and their use was not exclusive to OHS patients.

Maintenance of intravascular catheters was performed exclusively by the nursing staff from the intensive care units. Reusable pressure transducers (Gould Inc., Oxnard, Calif.) with disposable domes were used for monitoring pulmonary arterial, arterial, and left ventricular pressures. Every 8 h, all pressure transducers were recalibrated by the primary nurse using a technique that involved disconnecting the transducer from the dome and placing a few drops of sterile saline solution on the pressure-sensitive membrane of the transducer head. Gloves were not worn during recalibrating, but hand washing was performed before the procedure.

Pressure monitoring by PA-lines and A-lines was discontinued after an average of 48 h but was kept unchanged for longer periods if it was deemed necessary. IABPs were kept in place for variable lengths of time, although frequently they were removed at the same time as the PA-line. When the pressure monitoring was discontinued, the disposable dome was used as a protective device for the reusable transducer head. Occasionally, a few drops of 2% glutaraldehyde were placed on the transducer head before the protective dome was replaced, although this was not uniformly done throughout the hospital and was never done in the CCU during the outbreak period.



*Per 100 CCU patient discharges.

FIG. 1. Epidemic curve of *S. marcescens* bacteremia cases at hospital A, 1987 to 1988.

RESULTS

Case ascertainment. During the epidemic period (16 July to 27 September 1988), seven cases of *S. marcescens* bacteremia occurred (Fig. 1). All were in CCU patients, five of whom (71.4%) had undergone OHS. No cases of *S. marcescens* bacteremia were identified outside the CCU during the epidemic or preepidemic period. The incidence of nosocomial *S. marcescens* bacteremia in the CCU was significantly increased in the epidemic period compared with the preepidemic period (1 January 1986 to 15 July 1988) (3 of 2,618 versus 7 of 250 patients; $P < 0.001$).

Analytic epidemiology: case-control study results. There were no significant differences between case and control patients in mean age; weight; APACHE II admission score; number of admission diagnoses; number of antimicrobial agents administered before the day when the *S. marcescens*-positive blood culture was obtained; number of days on mechanical ventilation; and exposure to percutaneous transluminal coronary angioplasty, cardiac catheterization, or hyperalimentation. Although 71% of case patients and 38% of control patients underwent OHS, this difference was not statistically significant.

Case patients were found to have significantly longer lengths of stay in the hospital and in the CCU and were significantly more likely to have received antimicrobial agents or to have been exposed to mechanical ventilation before the day of the positive blood culture (Table 1). Case patients were also significantly more likely than control patients to have had a PA-line or an IABP in the 3 days before the positive blood culture. More case patients than control patients had an A-line, although this difference did not reach statistical significance. The mean duration of PA-line or A-line exposure at a specific site was significantly greater in case patients than in control patients. The mean durations of IABP exposure did not differ between these groups. Mortalities were similar between case patients and control patients (1 of 7 versus 2 of 21; $P = 0.58$).

To further clarify the association between some of the risk factors and infection that were identified in the univariate analysis, we performed a multivariate analysis. The variables used in the logistic regression model included receipt of antimicrobial agents before the day when the *S. marcescens*-

TABLE 1. Assessment of potential risk factors for *S. marcescens* bacteremia at hospital A, 16 July to 27 September 1988

Variable	Cases (n = 7)	Controls (n = 21)	P Value
Receipt of antimicrobial agents before day when *S. marcescens*-positive blood culture was obtained (no. of patients)	7	11	0.03
Mechanical ventilation (no. of patients)	7	9	0.009
Duration between admission to the hospital and *S. marcescens* bacteremia (days)	9.9 ± 5.7[a]	3.0 ± 2.8	0.0002
Duration between admission to the CCU and *S. marcescens* bacteremia (days)	8.3 ± 5.2	2.1 ± 1.5	0.0001
PA-line transducer[b] (no. of patients)	7	8	0.005
Duration of PA-line transducer (days)	6.4 ± 5.3	2.1 ± 1.8	0.045
IABP pressure transducer[b] (no. of patients)	7	6	0.001
Duration of A-line pressure transducer (days)	7.3 ± 4.9	2.3 ± 1.9	0.004

[a] Mean ± standard error.
[b] Exposure in the 3 days before *S. marcescens* bacteremia.

positive blood culture was obtained, exposure to mechanical ventilation, exposure to a PA-line transducer, exposure to an IABP pressure transducer, and exposure to an A-line pressure transducer. Only exposure to an IABP pressure transducer (P = 0.012) and exposure to a PA-line transducer (P = 0.06) were significant independent predictors of *S. marcescens* bacteremia.

Laboratory results. (i) Blood and environmental culture results. Two of the case patients had other microorganisms identified in the blood culture from which *S. marcescens* was recovered; one blood culture had *E. cloacae* and another had *Klebsiella pneumoniae*. In only one case patient was *S. marcescens* isolated from a site other than blood; in this patient, *S. marcescens* was isolated from purulent drainage at the site of the PA-line 3 days before the positive blood culture.

S. marcescens was recovered from six of seven transducers cultured. In addition, cultures from four transducers were positive for *E. cloacae*, and cultures from two transducers were positive for *Pseudomonas aeruginosa*.

(ii) Serotyping results. Two *S. marcescens* flagellar serotypes, Oundetermined:H1 (Ound:H1) and Oundetermined:H18 (Ound:H18), were identified in blood culture isolates from patients (Table 2). All *S. marcescens* isolates recovered from transducers were serotype Ound:H1. The isolates from the cultures of the PA-line tips of two different patients were serotypes Ound:H1 and Ound:H18; the isolate from the culture of one A-line tip was serotype Ound:H1. Of all positive line or transducer cultures, eight of nine isolates (89%) were serotype Ound:H1 and one (11%) was serotype Ound:H18.

Four of five cultures obtained from transducers in storage on 27 September 1988 in the CCU were positive for *S. marcescens*; all had the same serotype (Ound:H1) as that of the most prevalent strain found in the case patients' blood culture isolates. In summary, of the 14 blood and transducer *S. marcescens* isolates sent to the CDC for serotyping, 12 (85.7%) were found to be serotype Ound:H1 and 2 (14.3%) were serotype Ound:H18. Of 1,640 *S. marcescens* isolates in our collection from outbreak situations, only 1.6% are serotype Ound:H1. Although this does not represent the incidence in a general population, it does represent *S. marcescens* isolates from outbreaks investigated by the CDC.

(iii) Plasmid analysis and antimicrobial suceptibility results. Plasmids were not detected in either the blood or transducer *E. cloacae* isolates. All *E. cloacae* isolates tested were resistant to ampicillin and cefazolin (MIC, >32 μg/ml) and susceptible to trimethoprim-sulfamethoxazole (MIC, 10 μg/ml), tetracycline (MIC, <4 μg/ml), and gentamicin (MIC, 0.5 μg/ml).

DISCUSSION

It is estimated that in the United States approximately 80% of patients admitted to intensive care units annually are exposed to intravascular pressure monitoring devices (5). The increase in the use of hemodynamic monitoring has resulted in an increased incidence of nosocomial bacteremia (1, 11, 13). This epidemiologic investigation confirmed that contaminated pressure monitoring transducers were the common-source reservoir of *S. marcescens* and *E. cloacae* for a cluster of bacteremic patients. Case patients were more likely to be exposed to both IABP pressure transducers and PA-line transducers than were control patients. The univariate analysis showed other risk factors, such as receipt of antimicrobial agents before the day of collection of the positive *S. marcescens* blood culture and exposure to mechanical ventilation, to be statistically associated with infection. However, multivariate analysis, which controls for the independent influence of these various factors, identified only exposures to an IABP pressure transducer and to a PA-line transducer as risk factors for infection.

Further evidence implicating the pressure monitoring transducers as the reservoir of *S. marcescens* and *E. cloacae*

TABLE 2. Results of serotyping clinical and environmental isolates of *S. marcescens* at hospital A

Patient	Date (mo/day/yr)	Serotype				
		Blood culture	Transducer in use		Intravascular tip	
			PA-line	A-line	PA-line	A-line
1	9/18/1988	Ound:H1	NC[a]	NC	Ound:H18	NG[b]
2	9/19/1988	Ound:H18	NC	NC	NG	NG
3	9/20/1988	Ound:H1	NC	NC	NG	NG
4	9/26/1988	Ound:H1	Ound:H1	Ound:H1	NG	Ound:H1
5	9/27/1988	Ound:H1	NG	NG	Ound:H1	NG

[a] NC, Not cultured.
[b] NG, No *S. marcescens* growth.

is found in the microbiologic results. The two epidemic strains of *S. marcescens* identified in the patients' blood (Ound:H1 and Ound:H18) were also recovered from transducer and intravascular cultures. The *E. cloacae* isolates from one case patient, two in-use transducers (from the same case patient), and two stored transducers had identical antimicrobial suceptibility patterns. Both these findings support the hypothesis of a common-source outbreak.

Although our case-control study successfully identified the device responsible for the transmission of infection, the fact that six of the seven transducers cultured were colonized with *S. marcescens* and other gram-negative rods raises the question of why the patients in the control group who were also exposed to pressure transducers did not get infected. The generally shorter periods of exposure for the control patients may have put them at a significantly lower risk of bloodstream infection. Furthermore, we hypothesize that either one transducer became colonized with more than one gram-negative microorganism (either different serotypes of *S. marcescens* or two species) and then the other transducers were cross-contaminated or that two or more transducers became colonized with different gram-negative microorganisms and then cross-contamination of the other transducers occurred.

According to some studies, the membrane of the disposable domes used with the pressure transducer shields the transducer from the intravascular fluid circuit, thereby eliminating the need for the transducer to be sterile (9). However, despite the presence of a structurally intact membrane, contamination of the fluid circuit may occur via the hands of the person who assembles, calibrates, or in other ways manipulates it (4, 7). The use and maintenance practices of transducers in the CCU during this outbreak period could have allowed the *S. marcescens* and *E. cloacae* epidemic strains to persist and be spread to additional transducer heads. During the epidemic period, transducers used in the CCU were only hung to dry between patient uses and did not receive either low-level or high-level disinfection or sterilization. The disposable dome was left in place on the transducer between uses, interfering with the drying process and creating a closed space between the transducer head and the dome membrane where bacteria could proliferate. Multiple factors, such as contamination of open ports, handling of the transducers during recalibration, line manipulations during changes of fluid administration tubing, and failure of all personnel to wash their hands before manipulating the system, could have increased the chances of contamination of the pressure monitoring system. When control measures, which consisted mainly of eliminating the use of any reusable nonsterile transducer in favor of sterile disposable transducers that require virtually no manipulation, were instituted, no additional cases of gram-negative bacteremia occurred in the CCU during the subsequent 9 months.

The results of our investigation document a previously undescribed potential reservoir for nosocomial bacteremia—the IABP pressure monitoring transducer. The potential for the IABP pressure transducers to serve as a reservoir for infections is high, because they have the same structural design and maintenance involved as transducers used to monitor pulmonary arterial or peripheral arterial pressures. Hospital records did not contain the information needed to link the stored transducers that were cultured to a specific pressure monitoring site. Nevertheless, the results from our case-control study show a strong association between exposure to an IAPB pressure transducer and case patients, indicating that nosocomial bacteremia should be considered a possible complication of the use of any catheter with a transducer, including IABPs, in the CCU patient.

LITERATURE CITED

1. **Beck-Sague, C. M., and W. R. Jarvis.** 1988. Epidemic bloodstream infections associated with pressure transducers: a persistent problem. Infect. Control Hosp. Epidemiol. **10**:54–59.
2. **Birnboim, H. C., and J. Doly.** 1979. A rapid alkaline extraction procedure for screening recombinant plasmid DNA. Nucleic Acids Res. **7**:1513–1523.
3. **Centers for Disease Control.** 1982. Guidelines for prevention of intravascular infection. Infect. Control **3**:61–72.
4. **Donowitz, L. G., F. J. Marsik, J. W. Hoyt, and R. P. Wenzel.** 1979. *Serratia marcescens* bacteremia from contaminated pressure transducers. J. Am. Med. Assoc. **242**:1749–1751.
5. **Donowitz, L. G., R. P. Wenzel, and J. W. Hoyt.** 1982. High risk of hospital-acquired infection in the ICU patient. Crit. Care Med. **10**:355–357.
6. **Ewing, W. H.** 1986. Ewards and Ewing's identification of *Enterobacteriaceae*, 4th ed., p. 431–440. Elsevier Science Publishing, Inc., New York.
7. **Henderson, D. K., R. Baptiste, J. Parrillo, and V. J. Gill.** 1988. Indolent epidemic of *Pseudomonas cepacia* bacteremia and pseudobacteremia in an intensive care unit traced to a contaminated blood gas analyzer. Am. J. Med. **84**:75–81.
8. **Knaus, W. A., E. A. Draper, D. P. Wagner, and J. E. Zimmerman.** 1985. APACHE-II: a severity of disease classification system. Crit. Care Med. **13**:381–386.
9. **Platt, R., J. L. Lehr, S. Marino, A. Munoz, B. Nash, and D. B. Raemer.** 1988. Safe and cost-effective cleaning of pressure-monitoring transducers. Infect. Control Hosp. Epidemiol. **9**: 409–416.
10. **Siegel, S.** 1981. Nonparametric statistics for behavioral sciences, p. 184. John Wiley & Sons, Inc., New York.
11. **Stratton, C. W.** 1983. Bacterial infection from intravascular monitoring devices. Infect. Control **4**:339–401.
12. **Traub, W.H., and I. Kleber.** 1977. Serotyping of *Serratia marcescens*: evaluation of Le Minor's H-immobilization test and description of three new flagellar H antigens. J. Clin. Microbiol. **5**:115–121.
13. **Wenzel, R. P., R. L. Thompson, S. M. Landry, B. S. Russell, P. J. Miller, S. Ponce de Leon, and G. B. Miller.** 1983. Hospital-acquired infections in intensive care unit patients: an overview with emphasis on epidemics. Infect. Control **4**:371–375.